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Experimental investigation on cement grouted bituminous pavement

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ABSTRACT

The flexible roads have the advantage of good riding surface while the concrete roads are more durable and required less maintenance than the flexible / bituminous pavement. The costs of the concrete roads are high on the initial basis while the initial cost of the flexible pavement is lower than the concrete roads and therefore the reason behind the construction of such pavement widely. There is an alternative to this flexible and rigid pavement and that is the semi-flexible pavement which has the advantage of rigid pavement and flexible pavement. The present work consists of the experimental investigation on such semi-flexible pavement. The rice husk ash, fly ash and marble dust was used in the partial replacement of the cement to prepare the grout. This grout is then poured in the well compacted bitumen coated aggregates. The compressive strength found to be in the range of 25 N/mm^2 to 30 N/mm^2 for the case of rice husk ash. Since fly ash is readily available in the nearby region it found to be economical solution for the grout preparation when cement grouted bituminous pavement is to be prepared.

1. INTRODUCTION

The individual blocks are laid in very predetermined pattern so that a surface is created interlocked with the joint filler, in concrete pavement, has some discontinuities rather than the continuous paving (Lin, Kim, Ryu, Hao, Ge, & Cho, 2017). Concrete block pavements have a wide range of applications in the pavement structure (Mampearachchi & Senadeera, 2014). The concrete block pattern is proved to be aesthetic for platforms, pedestrian zones as well as city streets (Schexnayder, 2004). The impermeable and permeable interlocking concrete block pavements (ICBP) have been constructed in the port authority of New York and New Jersey and this is for the purpose of the purpose of container handling equipments (Sieglen & Langsdorff, 2004). For good performance the semi-flexible pavement has been used widely but the study to find the effect of composition and formulation on grout material was not carried out extensively (Zhang, Cai, Pei, Li, & Chen, 2016).

To reduce the maintenance cost as well as the construction cost the interlocking block pavement is good option to use in the low traffic in case of rural road (Ma, Hou, & Wu, 2009). The numbers of limitations are associated with the methods available and it includes the inadequate characterization of the subgrade soil and paving materials (Rada, Smith, Miller, & Witczak, 1990). Additional limitations of surface reflection tests will arise from different parameters like soil stratigraphy, stiffness of the soil adjacent to the pile (Finno, 1-D wave propagation techniques in foundation engineering, 2010). The different non destructive testing methods consisting ground penetrating radar, infrared thermography, impact echo, electrical resistivity, ultrasonic surface waves, etc (Gucunski, Nazarian, Imani, & Azari, 2014). The researcher investigated that slab impulse response method can become standard non destructive testing method to check the quality of pavement during the construction phases (Mahedi, Sahadat Hossain, Ahsan, Ahmed, Khan, & Greenwood, 2017).

Based upon the local conditions the different engineering tests can be carried out as the researcher have recommended for the typical application with proper strengthening patterns for ISR and in different thickness of SRP (Wu & Zhang, 2016). The cast in-situ concrete block needed lesser thickness of granular base to design the pavement (Teiborlang L. et al., 2005). The ground penetrating radar for detection of voids and FWD for bearing capacity used were found to be very efficient method of testing (Ni & Cheng, 2011).

The study was conducted on fiber-reinforced preplaced aggregate concrete. The formwork was filled with the aggregates then the premixing and preplacing of steel fibers were carried out, afterwards the flowable grout was injected in the formwork (Nehdi, Najjar, Soliman, & Azabi, 2017). Taguchi method proved to be successful tool to obtain the optimum conditions for different cases (Tan, Zaimoglu, Hinislioglu, & Altun, 2005). The mechanical performance of the semi-flexible pavement will be better (Yang & Weng, 2015). The air void of matrix asphalt mixture should reach up to 21% for grouting the high performance cement pastes (Cai, Pei, Luo, Zhang, Li, & Chen, 2017).

The compressive strength of the hydrated hot mix grouted macadam was higher than that of hydrated cold mix grouted macadam (Setyawan, 2013). The grouted pavement where the material consists of a porous asphalt skeleton having 25-30% voids and that filled with cementitious grout has been used as a specialist surfacing (Oliveira, Thom, & Zoorob, 2008).

From the above research work it was found that the cement grouted bituminous pavement needs more experimental investigations. The present work consists of the laboratory testing on the cement grouted bituminous pavement.

2. METHODOLOGY

Flexible road are the most common types of road pavement used for motorways in India and around the world. The bituminous wearing of such road often suffers from damage to wet weather, which is aggravated in cities by flooding during monsoons. Road crossings, parking lots and bus stops are seriously damaged due to frequent braking and fuel leakage. There is a need for a long wearing course that is (i) strong enough to withstand braking and accelerating traffic; (ii) resistance to fuel; (iii) impermeable to water; and (iv) resistant to moisture. There is a need for a low cost of wearing to address the above problem. Studies at IIT Kharagpur have shown that a bituminous road, covered with bitumen, impregnated with cement mortar, can form a long process of wear. The ACC Research Institute developed a similar product called ACC Marg, which was used in several locations. Flexible, rigid and composite pavements are the most common. Another type of pavement obtained by brewing closed, graded bitumen of a treated aggregate with cement (or a polymer-based suspension) is also available, and is called a cementitious mixed bituminous mixture. This work applies to the Cement Grouted Bituminous Macadam (CGBM).

In such a layer, first, the unit sizes of aggregates with a flakiness index of less than 30% having an aggregate skeleton with a void greater than 25% that is larger than a traditional densely graduated bituminous mixture, mixed with a bituminous binder, the laid base and is lightly sealed. Sometimes the fibers are added to prevent the fusion of the binder material. Then, a sufficiently fluid cement solution is introduced to fill the voids with gravity. This cement solution is prepared by mixing the suitable proportions of

cement, fine sand and water. Appendices such as micro silica, ash, super plasticizer can be added in such a way that the solutions fall into the cavity to conveniently fill all voids and achieve the required strength. The flow capacity of the solution plays an important role in the development of the strength of the CGBM.

Benefits of CGBM

- Resistance to fuel leakage
- Resistance to permanent deformation
- Resistance to wearing / wearing
- Resistance to water damage
- Flexibility
- Lack of joints
- High static bearing capacity and voltage distribution
- High thermal sensitivity
- Well opposite property resistance
- Fast constructive and opening for movement

These benefits allow the CGBM to be mixed to provide some individual constraints related to cement concrete and bituminous mix. Past researchers conducted laboratory tests on rigidity, compressive and compressive strength, Marshall's strength, thermal expansion coefficient, low temperature fracture, fatigue properties of CGBM and apparently shown to be satisfactory. The consistency and amount of binding material, the size and gradation of the aggregates, the loading frequency, the strength of the solution and the shrinkage potential, temperature, etc. are observed.

In this variant, the construction of an open graded bitumen rolling stock is filled with a cement mortar, although it can be used for heavy traffic also if the base is rigid. Such road benefits from the flexibility of the pavement, with the advantage of a rigid pavement that is resistant to damage due to leakage of water and fuel. The study includes the properties of the solution, the method of building a cementitious granular bituminous layer, as well as the principles of designing the pavement. Researchers should periodically keep track of the road and send their feedback to the Indian Roads Congress for future review of the study.

Open granular aggregates covered with bitumen of about 3.25% to 4.0% are laid by the asphalt spreader and sealed with a roller to achieve sufficient air cavities in the bituminous layer after the surface cools close to ambient temperature. The cement solution overflows the surface, which penetrates and fills the cavity and forms an impenetrable layer. The courthouse extends across rural roads in the Great Depression Zone of West Bengal, on a bridge in Mumbai, on the roads of municipal corporations in Mumbai and on several roads at Surat Corporation built over the past ten years. Roads in Surat, Dadar flight in Mumbai, etc. have yielded good performance. In hot summer, cement bleeding or torsion is not noticeable.

Self-made Grout Using Fly-Ash

The grout was prepared by referring the IS code 4031. Accordingly, the water to cement ratio taken was 0.5 and the percentage of cement, sand, fly ash and water taken is as follows:

- Cement = 40%
- Fine sand = 20%
- Fly-ash = 20%
- Water = 20%

Take Admixture 0.6% to 0.8% of the total weight of grout.

Self-made Grout Using Rice Husk

The grout was prepared by referring the IS code 4031. Accordingly, the water to cement ratio taken was 0.7 and the percentage of cement, sand, rice husk and water taken is as follows:

- Cement = 40%
- Fine sand = 12%
- Rice-Husk = 20%
- Water = 28%

Take Admixture 0.6% to 0.8% of the total weight of grout.

Self-made Grout Using Marble-Dust

The grout was prepared by referring the IS code 4031. Accordingly, the water to cement ratio taken was 0.5 and the percentage of cement, sand, marble dust and water taken is as follows:

- Cement = 40%
- Fine sand = 20%
- Marble-Dust = 20%
- Water = 20%

Take Admixture 0.6% to 0.8% of the total weight of grout.

a) Method 1: Bitumen Coated Aggregate Up to 75 mm Depth Then Filled With Grout

- Take 4 moulds of size 150mm x 150mm.
- Apply grease or oil on the inner surface of mould for the easy removal of cubes after 24 hours.
- Fill the bitumen coated aggregate upto 75mm depth in each of the mould.
- Pour the prepared grout in the coated aggregate filled mould.
- While casting special care shall be taken while tamping. Shake the mould slightly so that the grout would penetrate properly through the coated aggregate.
- At last, place these casted moulds on table vibrator for proper vibration.
- Lastly, keep all these casted moulds for 24 hours for drying purpose and remove them after 24 hours for curing purpose.

b) Method 2: Alternate Layers of Bitumen Coated Aggregate And Grout

- Take 4 moulds of size 150mm x 150mm.
- Apply grease or oil on the inner surface of mould for the easy removal of cubes after 24 hours.
- Fill those mould with alternate layers of bitumen coated aggregate and prepared grout.
- While casting special care shall be taken while tamping. Shake the mould slightly so that the grout would penetrate easily through the coated aggregate after each layer.
- At last, place the casted moulds on table vibrator for proper vibration.
- Lastly, keep all these casted moulds for 24 hours for drying purpose and remove them after 24 hours for curing purpose.

3. DESIGN OF CEMENT GROUT

The cement solution consists of cement, sand, water and mineral additives such as ash, micro-silica; very thin sand. Suitable chemical additives for improving fluidity and other properties in an appropriate proportion, in order to produce a material that easily flows into the cavity of the bituminous mixture. And at the same time, keep force in order to sustain traffic downloads. Despite the fact that the aggregates are interlaced through the solution and carry most of the load applied in motion, the solution should be strong enough to withstand the stress caused by the motion without crushing. A part of the sand and fluid may change to increase the strength of the solution and the flow. Flux ash and silicon dioxide, also known as micron disperse silica, are used to increase productivity, and super-plasticizer / chemical additives are used to obtain the required yield when reducing water content for a cement mortar without loss of strength. The polymeric additive in powder form or liquid form provides early strength to the solution.

Grout must meet the following criteria:

- It should be sufficiently leaked so that it could occupy the void of the cumulative skeleton. However, if the viscosity is low, the solution flows through aggregate pores, and strength will be achieved.
- The small particles present in the solution should not create difficulties for the easy flow of solution through aggregate cavities.

Bituminous Grout

Method 1:- Bitumen Coated Aggregate filled up to 75mm depth And then Filled with Grout containing Fly Ash:-

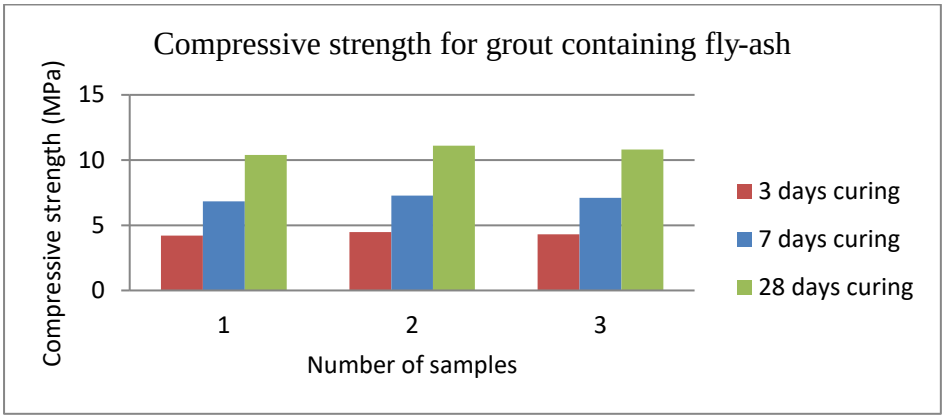

Figure 1 Compressive strength for grout containing fly-ash (150 mm x 150 mm mould size)

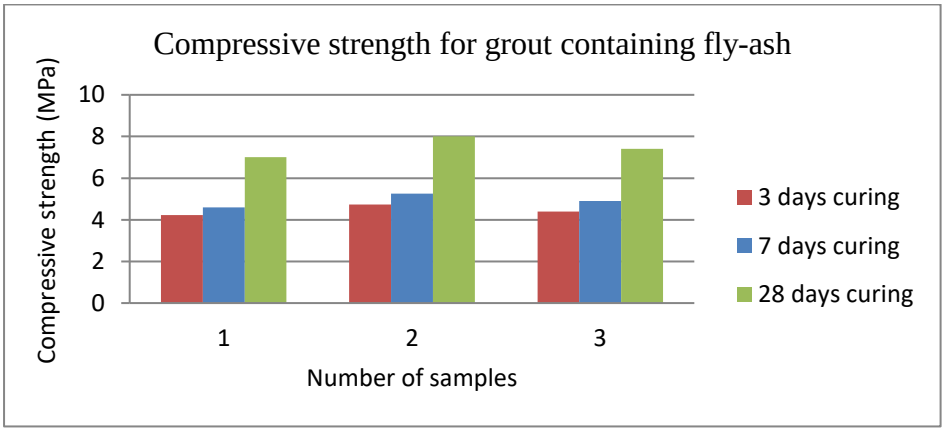

Figure 2 Compressive strength for grout containing fly-ash (150 mm diameter x 250 mm height cylinder)

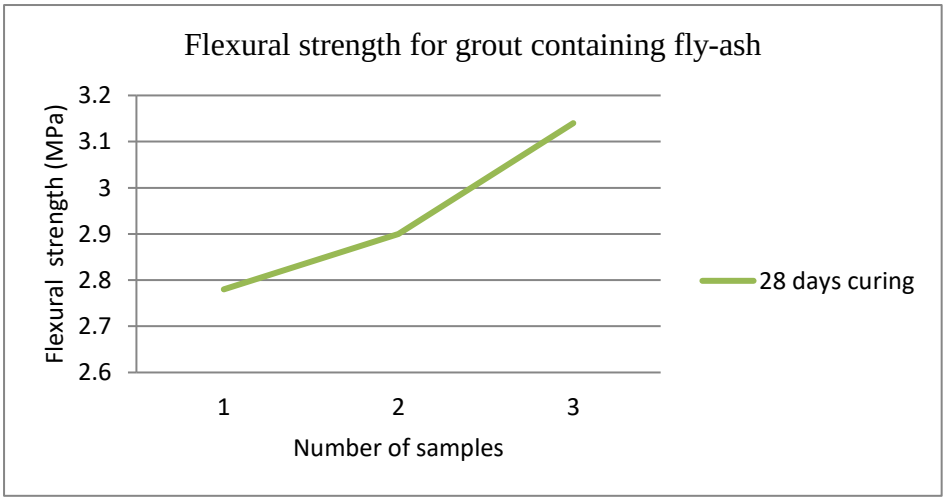

Figure 3 Flexural strength for grout containing fly-ash

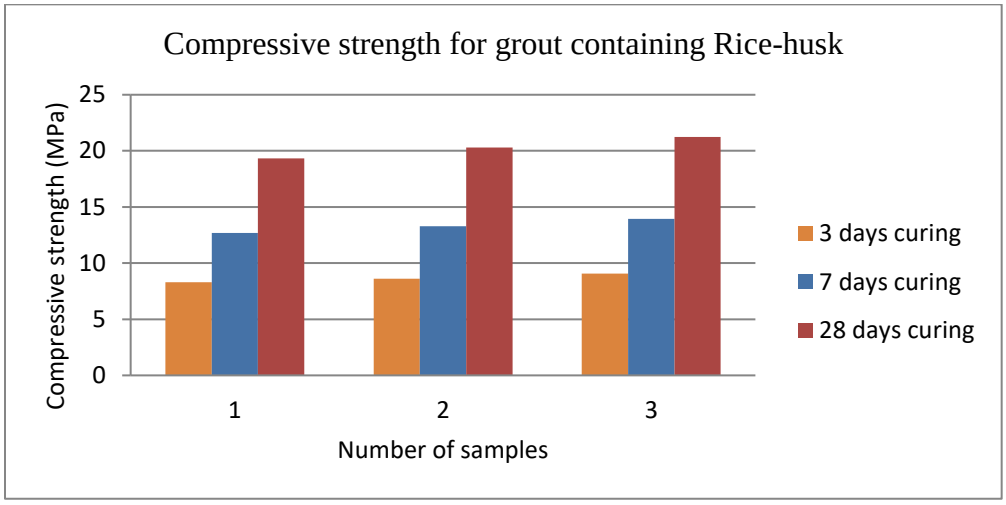

Figure 4 Compressive strength for grout containing Rice-husk

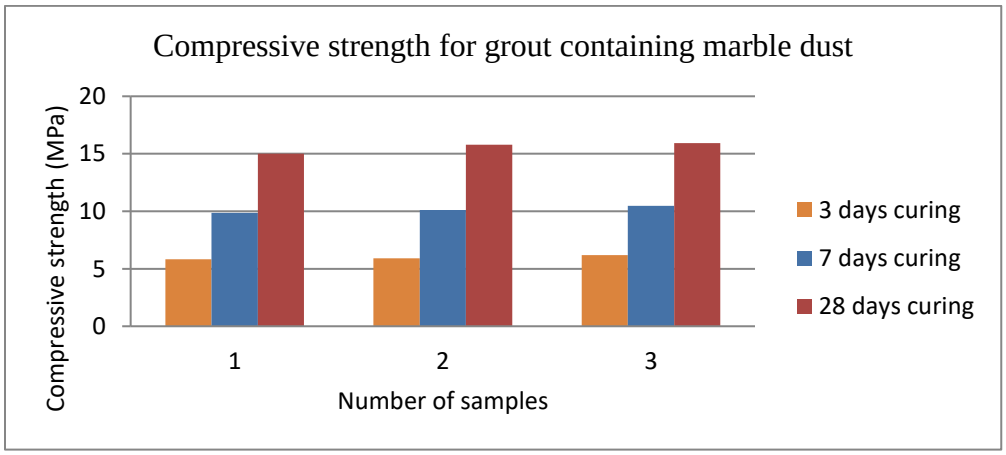

Figure 5 Compressive strength for grout containing marble dust

Method 2:-Filling of Bitumen Coated Aggregate in 3 layers and filling of Grout

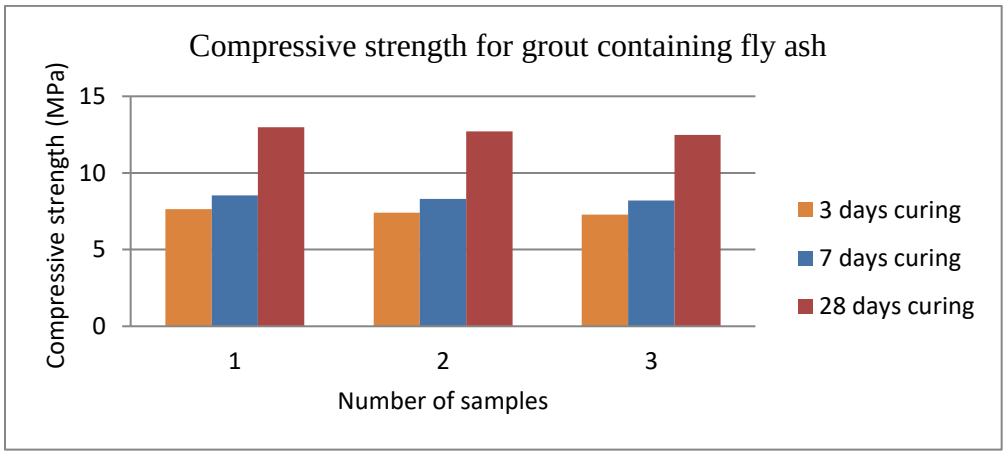

Figure 6 Compressive strength for grout containing fly ash (150 mm x 150 mm mould)

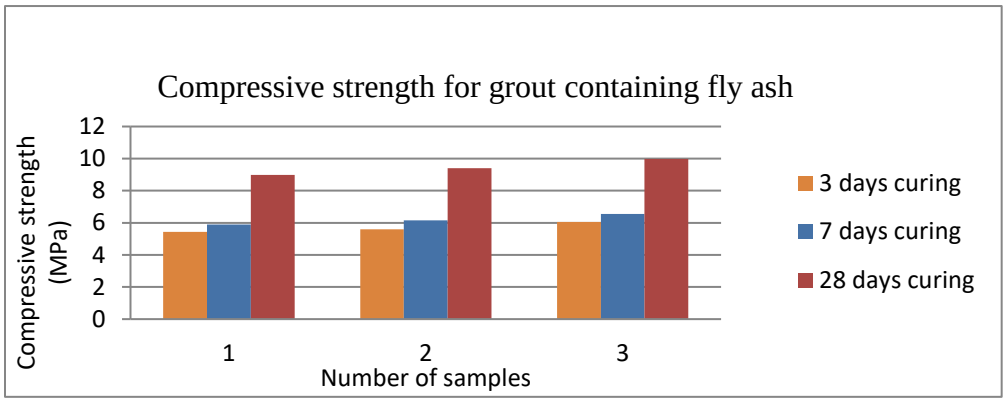

Figure 7 Compressive strength for grout containing fly ash (150 mm diameter x 250 mm height cylinder)

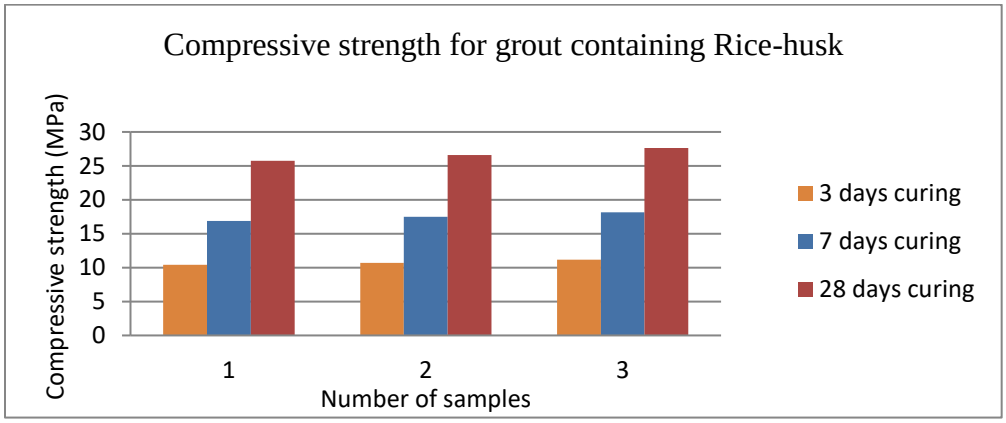

Figure 8 Compressive strength for grout containing Rice-husk

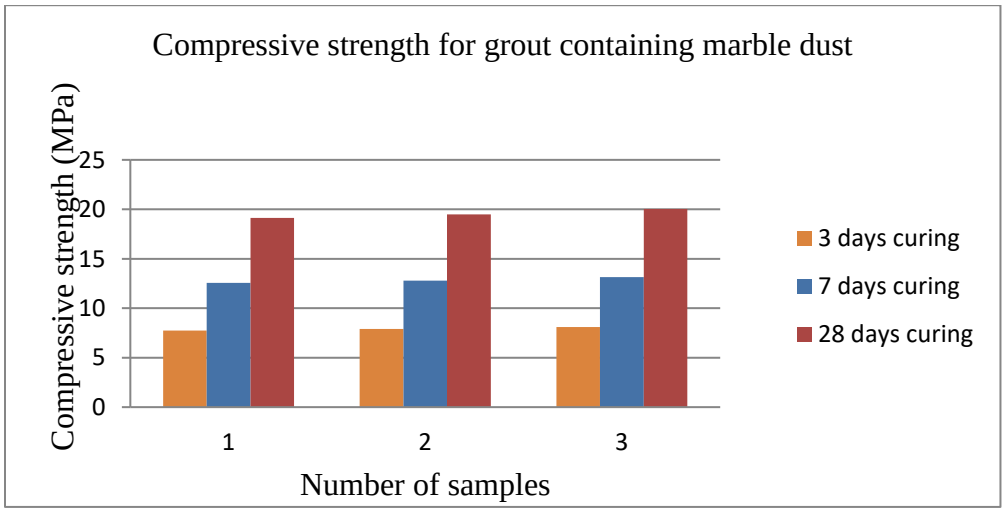

Figure 9 Compressive strength for grout containing marble dust

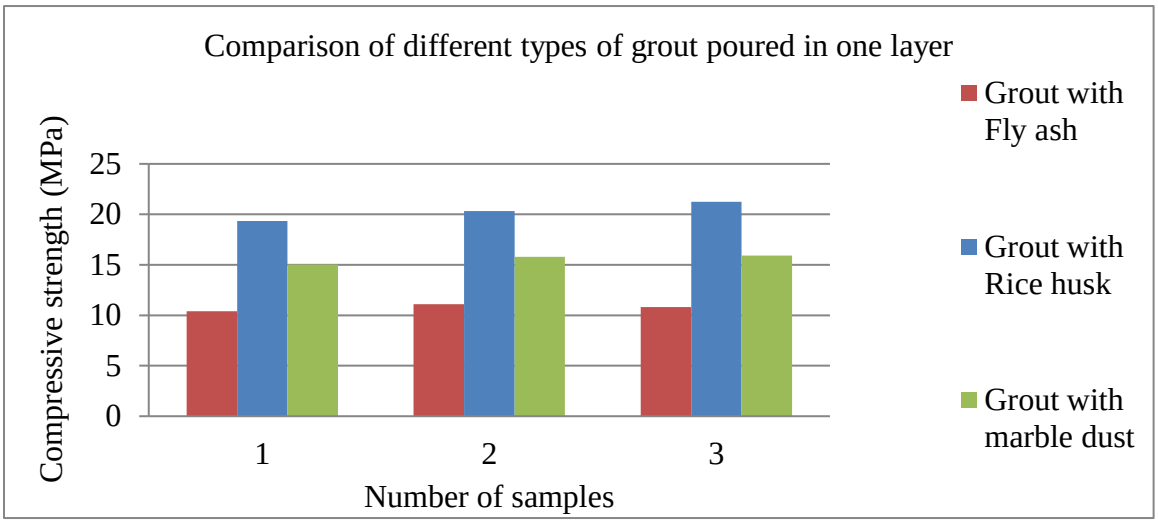

Figure 10 Comparison of different types of grout poured in one layer

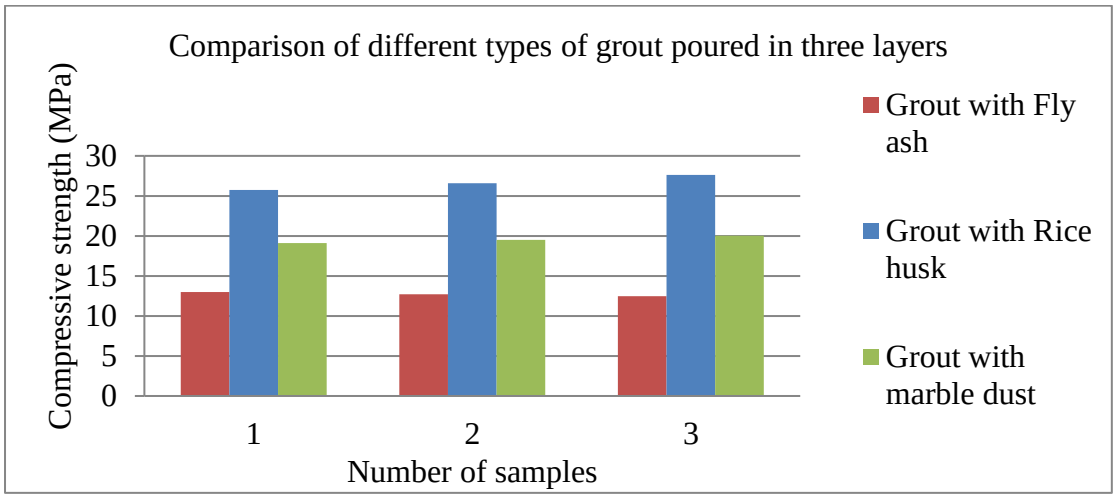

Figure 11 Comparison of different types of grout poured in three layers

The above figures 1-11 shows that the compressive strength was higher in case of bitumen coated aggregates are filled in two layers and then the grout was poured. The rice husk ash gave good results as compared to the fly ash and marble dust. The compressive strength found to be in the range of 25 N/mm^2 to 30 N/mm^2 for the case of rice husk ash. Since fly ash is readily available in the nearby region it found to be economical solution for the grout preparation when cement grouted bituminous pavement is to be prepared.

The test was not possible for the higher size of aggregates than 20 mm since the penetration of grout in lower size of aggregates was a bigger problem. While the bitumen was not possible to coat properly on higher size of aggregates the penetration of grout up to full depth was not achieved.

4. CONCLUSIONS

From the laboratory testing on the cement grouted bituminous pavement it is observed that the rice husk ash as partial replacement of the cement to prepare the grout gave good results in terms of the compressive strength. The fly ash which is readily available nearby location gives a good and economical option for the preparation of the grout. The compressive strength up to 30 N/mm^2 for the case of rice husk ash in cement grouted bituminous pavement is good option for the alternative to flexible or rigid pavement.

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